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Differences in wheelchair propulsion technique between trained and untrained subjects

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XIIIth International Congress on Biomechanics

**A Biennial Congress of
The International Society of Biomechanics (ISB)**

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Book of Abstracts

Edited by:



**R.N. Marshall
G.A. Wood
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**The Department of Human Movement Studies
The University of Western Australia**

Preface

The XIIIth Congress on Biomechanics is an official biennial meeting of the International Society of Biomechanics (ISB) whose primary purpose is "to promote and stimulate development of all areas of biomechanics at the international level". This publication is testimony to the successfulness of that mandate. Contained herein are almost 400 two-page abstracts of original research being conducted by scientists from 30 different countries. Both the quality of that work and the diversity of topic are indicative of a very vital discipline, and one which we are honoured to be able to serve as Congress organiser and host.

In 1989 the ISB departed from its tradition of publishing its Congress Proceedings as a monograph series, preferring an immediately available précis of current research in the form of a Book of Abstracts. It is nevertheless our belief that this volume will make a valuable contribution to the research literature and also serve to document the progress of the field of biomechanics. We thank all those contributors whose work has made this possible, and hope that readers will be stimulated by their efforts. The strict deadline that was required for the pre-Congress printing of this volume has inevitably meant that a few abstracts contained herein were ultimately not presented at the Congress. Furthermore, the contents reflect the opinions of the contributors and not necessarily those of the Organising Committee nor the International Society of Biomechanics. Considerable effort has been devoted to the correction of obvious errors and omissions, as well as in producing a consistent presentation format, and the organisers are very indebted to the Scientific Sub-Committee and the clerical staff of the Department of Human Movement Studies for their help in this regard.

In addition to this book of abstracts a special issue of the *Journal of Biomechanics* will be published in 1992 containing the full-length communications of the keynote and young investigator award-winning presenters. The clinical biomechanics award-winning paper will be published in the *Clinical Biomechanics* journal. These publications will provide easily accessible reading of state-of-the-art discourses on biomechanics ranging from morphology to movement; athletic to abnormal; shoes to simulations. These writings too will reinforce for readers the broad perspective of biomechanics and the quality of the work of members of the International Society.

Graeme A. Wood, PhD

On behalf of the XIIIth Congress Organising Committee

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MAXIMUM PERFORMANCE OF WHEELCHAIR TRACK ATHLETES

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INTRODUCTION

Maximum performance capacity of wheelchair athletes has been determined mainly for physiological parameters (1,2). Limited data are available however, regarding biomechanical indices of performance. The study of biomechanics may help clarify the low, gross mechanical efficiency in wheelchair arm work, whereas analysis of elite wheelchair athletes renders insight in both the summit which may be attained in sports training and rehabilitation and in the propulsion technique employed.

METHODOLOGY

Performance of wheelchair track athletes in a maximum aerobic wheelchair exercise test was determined on a special purpose wheelchair simulator (3) during the 1990 World Games and Championships for the Disabled (Assen, The Netherlands). Preliminary results of the maximum performance of 23 male athletes (ISMGF/ISOD class T-4; mean+SD:age= 27yrs+5.4 and body weight=59.8kg+11.8) are presented. The athletes conducted a progressive maximum exercise test (+10W.min⁻¹; V=1.39m.s⁻¹; rim radius:0.26m) to exhaustion. Mean and peak values of the forces applied to the hand rims were determined for the right hand side. Net torque and power output parameters were determined for left and right sides. Parameters were sampled (65Hz) for 5 second periods during each workload and low-pass filtered. Physiological measures were taken continuously and maximum performance values were evaluated. Special attention was given to inter-individual variation and left to right differences (Students T-test; Pearson correlation; P<0.05).

RESULTS

A selection of data is given in Table 1. Values for mean external power output (Po(W)), peak power output (Pp(W)), peak torque (Mp(Nm)) and peak forces (Fx,Fy,Fz(N)) within the push phase are presented in conjunction with maximum heart rate (HF(b.min⁻¹)) and oxygen uptake (Vo(l.min⁻¹)) during the final minute of the test. Po varied between 1.19 and 2.83 W.kg⁻¹ (mean= 1.82+0.41).

Table 1. Peak Values Maximum Exercise Test (N=23)

	HF	Vo	Po	Pol	Por	Mp	Pp	V	Fx	Fy	Fz	FEF
Mean	183	2.25	105.7	51.7	54.0	86.5	384.4	1.31	123.6	17.5	188.5	69
SD	12	0.39	15.5	8.8	8.2	9.5	67.7	0.12	24.6	11.9	31.4	7
min	163	1.58	82.4	36.4	37.7	66.9	268.8	1.10	74.5	-1.9	135.7	56
max	208	3.18	141.3	68.7	72.5	107.5	500.6	1.55	172.6	39.1	262.6	80

The efficiency of torque production, defined as the mean value over the push phase of the ratio between the total force vector and the effective force (torque/rim radius), is indicated by FEF. A similar ratio for peak values within the push phase varied between 65 and 90%.

No clear relations were found with the test parameters presented here and the performance times in the track events. Mean values for left and right side (Pol, Por(W)) did show small differences which were statistically significant for the constituents of power output, the mean torque and velocity (V(m.s⁻¹); P<0.05).

DISCUSSION

Performance values (Vo, Po) were, as far as comparison was possible, in line with previous data of wheelchair athletes (1,4,5). Implicit variability in functionality and unspecificity

strokes showing the highest peak power output within the 30 s. sampling period; effective force F_m , calculated as $M \cdot r^{-1}$; Force vector F_{tot} ; and FEF being the ratio between both force parameters averaged over the push. From video stroke parameters begin angle BA and end angle EA were determined (Figure 1). Moreover trunk angle TA at the end of the push phase was calculated as the angle of vector C7 - wheel axle with the vertical.

Determination of group differences comprised Analysis of Variance ($p < 0.05$).

RESULTS

Table 1 lists anthropometric data diagram of wheelchair and results for the three groups. The WA group was able to produce a considerably higher power output P5, mainly because they attained a higher propulsion velocity V_p (Table 1). Examples for the total and effective force curves are illustrated in Figure 2. Despite a higher propulsion velocity WA's showed a higher FEF than AB's. Stroke parameters BA and EA and trunk angle TA did not differ between both groups. The NWA group had a lower P5 than the WA group. However NWA subjects showed a considerable variation in P5 and in FEF values while stroke parameters EA and TA were different from those for WA and AB.

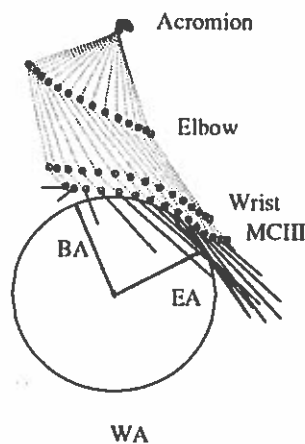


Figure 1: Stick diagram of wheelchair push.

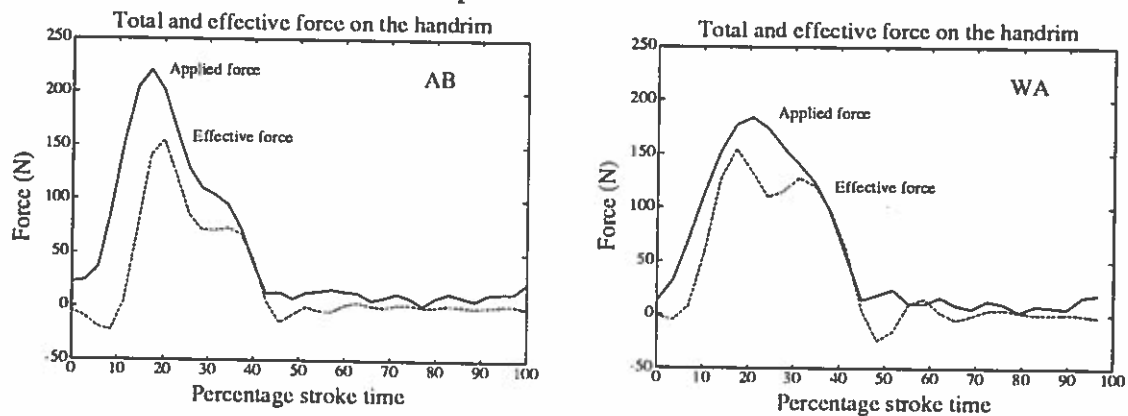


Figure 2: Typical examples of forces applied on the handrim.

DISCUSSION

For all three groups effectiveness of forces in terms of the optimal force vector direction was lower ($\pm 60\%$) than for submaximal values in a previous study ($\pm 70\%$, 1). Wheelchair athletes had a higher mean power output than both non-wheelchair athletes and able-bodied subjects. However peak power output and torque (P_p and M_p) did not differ (Table 1). FEF values for WA and AB seem to suggest that WA directed their propulsive force more effectively than AB. This despite the higher propulsion velocity which is assumed to be detrimental to co-ordination. It is expected that under equal velocity conditions FEF values will differ significantly. Results for the NWA group showed a deviating stroke pattern from both AB's and WA's. The large inter-group differences in P5 and FEF may have been caused by within-group differences in training

Seven normal adult males and one drop-foot male participated in this study. The subjects had previously given their written informed consent. The subjects walked barefoot at a freely chosen speed along a ten metre walkway which incorporated a pair of the pressure plates of the

METHODOLOGY

Lord et al. (1) elaborate on the developments in foot pressure measuring systems with a particular focus on the conditions of diabetes and rheumatoid arthritis. Grundy et al (2) illustrated the forces and centre of pressure paths in a normal subject walking barefoot and in shoes, and in a patient with hallux valgus and metatarsalgia and suggested that the function of the foot may be altered by footwear or appliances. Cavanagh (3) pointed out the need for centre of pressure averaging due to step to step variability and the loss of information which ensues from conventional averaging techniques. Motriuk and Nigg (4) later challenged this technique claiming that it did not allow for different abduction angles nor indeed did it conform to the conventional definition of average.

REVIEW OF RELATED LITERATURE

The path of the centre of pressure beneath the plantar surface of the foot during the stance phase of gait permits an objective assessment of foot pathology. This paper presents a comparison of the centre of pressure locus between a drop-foot patient and a group of normal subjects while walking barefoot over the Musgrave Footprint pressure measuring device.

INTRODUCTION

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CENTRE OF PRESSURE PATHS FOR NORMAL SUBJECTS AND A DROP-FOOT PATIENT

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2. Niesing, R. et al. Med Biol Eng & Comp 28:329-338, 1990.

	WA	NWA	AB	ANOVA
age (yrs)	32.0 ± 6.7	29.2 ± 12.5	23.8 ± 2.2	
weight (kg)	60.2 ± 8.0	73.2 ± 18.1	73.0 ± 4.6	*
P5 (W)	69.2 ± 9.8	57.7 ± 16.2	55.9 ± 4.5	*
MP (W)	37.4 ± 3.4	38.7 ± 9.6	40.9 ± 7.7	NS
Pp (W)	32.2 ± 3.6	28.9 ± 4.4	30.6 ± 5.2	NS
Vp (m.s ⁻¹)	2.8 ± 0.4	2.5 ± 0.4	2.4 ± 0.2	*
Flot (N)	100 ± 15	101 ± 18	101 ± 18	NS
FEF (%)	62.5 ± 7.3	59.7 ± 14.4	57.0 ± 4.0	NS
EA (deg)	68.0 ± 11.7	44.3 ± 6.7	64.8 ± 12.1	*
TA (deg)	7.7 ± 9.2	4.1 ± 3.9	8.0 ± 3.4	*

(* p < 0.05).

TABLE 1: Anthropometric data and wheelchair ergometer results measured on the right hand rim

and wheelchair design will be subject of further research.
It is concluded that WA's can produce considerably more power. They possibly direct their propulsive force better than AB's. FEF for WA is however also low. The relation between FEF and wheelchair design will be subject of further research.
experience. It is possible that the deviating stroke parameters are related to training experience, in particular their trunk motion control.